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A STUDY OF THE INHERITANCE OF DISEASE RESISTANCE AND FRUITING QUALITIES IN THE TOMATO

BY

JEAN PAUL GRIFFITH

B. S. Cornell University

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Jean Paul Griffith

ENTITLED A Study of the Inheritance of Disease Resistance and Fruiting Qualities in the Tomato

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science

J. W. Lloyd
In Charge of Thesis

Head of Department

Recommendation concurred in*

Committee on Final Examination*

*Required for doctor's degree but not for master's

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I. GENERAL DISCUSSION

Distribution of Fusarium Wilt (Fusarium lycopersici) of Tomatoes.

Fusarium wilt is distinctly southern in its range. It has caused its greatest damage in the south Atlantic and in adjacent States. Further north the disease becomes less frequent although it is of much importance in the tri-state tomato region, composed of New Jersey, Deleware and Maryland; in the Ohio Valley and south of the Missouri River. The disease extends northwards up the coast as far as Connecticut, where it occasionally occurs to a slight extent. In the northern tier of states the disease is practically absent in the field although occasionally destructive in the greenhouses. During the past few years fusarium wilt has not been of great importance in Florida, though in 1919 the estimated damage in the Miami and Homestead sections was 40 to 50% of the crop. Within the past two or three years records of Fusarium lycopersici have come from California and in 1919 the estimated damage for the State was 3%. In the Pacific Coast States there is some uncertainty in connection with the fusarium wilt because two diseases of a somewhat similar nature, the Summer Blight of California and the Yellow Blight of the Northwest (both fusaria), bring about symptoms which appear externally analagous. F. lycopersici is also mentioned as occuring in southern Colorado and in east central Arizona, but the extent and identity of the disease has not been definitely established there. (24).

It was during the 1919-20 season that the writer observed the importance of the wilt problem in the tropics. In Porto Rico, the early death of tomatoes due to the wilt has caused this hindrance to be one of the limiting factors in

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profitable production. Ordinarily tomatoes thrive and are amoung the few really promising vegetables which should be greatly improved upon in Porto Rico.

In the Spring of 1920 a third generation cross of the "Globe" on the native Porto Rican tomato (hybrid called P.R.443) was tested along side of eight American varieties for resistance to wilt. Plants of No.443 were very vigorous, early and showed no signs of wilt even when the set of fruit was the heaviest. Many of the American varieties, on the other hand, succombed to the disease at the time when the newly set fruit began to draw heavily on the roots for nourishment. In several cases only a few early fruits were obtained from each plant. Subsequent disease resistance tests with the P. R. 443 tomato have shown that its value lies not so much in its power of resistance as in other factors. The matter will be discussed more fully later.

Bewley (2) of the English Experimant Station reports that investigations on tomato wilt have been in progress there during the past two years. He claims that Verticillium albo-atrum is the cause of their wilt (Lea Valley area chiefly) owing to the fact that the average temperature of the green-house soils is suitable for this fungus and not high enough for Fusarium lycopersici. Occasionally in very hot summers, F. lycopersici is active in England, having been repeatedly isolat-ed during the month of July.

Importance-- Fusarium wilt is the most important disease of tomatoes in the South. It ranks second only to Septoria leaf spot in seriousness amoung tomato diseases of the entire United States. In spite of improved control measures, figures for 1919 indicated that the disease was more serious that year

than in the years previous. In the Southern states tomato production would undoubtedly become much more important if it were not for this persistant soil trouble. (24). McClintock states that many canning factories which had been built in Georgia for canning tomatoes were forced to close down because the necessary tonnage of tomatoes could not be supplied due to the ravages of fusarium wilt (20)

Some figures computed by the U. S. Department of Agriculture give the losses due to wilt in the 1919 tomato crop as follows:

State	Production (tons)	Loss %	Loss tons	State	Production(tons)	Loss %	Loss tons
Penn.	8201	1	99	Ind.	162,460	3	5602
Del.	11607	5	1116	Ill.	14,329	4	623
Md.	80899	7	13645	Mo.	22,139	5	1216
W.Va.	3607	3	161	Ky.	9,744	6	740
Ga.	---	40	---	Tenn.	22,952	10	3279
Fla.	56792	5	4369	Miss.	18,400	15	5412
Ohio	37988	10		Texas	17,700	1	197
Ark.	----	2	224	Cal.	199,052	3	6861
U. S.	887842	4.1	49077 tons loss.				

Figures from (24). Edgerton (10a) claims that 25% is a conservative estimate of the losses due to fusarium wilt of tomatoes in Louisiana.

II SYMPTOMS OF THE DISEASE

Characteristic injuries to plants at various stages of growth.

The disease, Fusarium lycopersici, attacks tomato plants at all stages of development. Experiments at the University of Illinois (4) have shown that where sterile tomato seeds are germinated in a moist chamber, previously sterile but later infected with F. lycopersici, the disease quickly attacks the young radicles of the germinating seeds. The progress of the disease may be easily followed in the roots as the latter turn brown and die from the attack. The fungus can sometimes be detected in small transplants by holding them in direct light.

The yellowish brown, threadlike lines are readily seen in the diseased plants when the fungus mycelium has developed sufficiently to cause bundle discoloration. (18).

The first symptom noticed in the field or greenhouse is that the lower leaves (usually the largest ones) turn rather pale and finally quite yellow. The leaves usually dry up from the tip and unless another tomato disease is present no spots will appear on leaves or stem. By cutting the leaf stalk with a knife darkened veins can frequently be seen. (18).

Plants of large size bearing the first blossom cluster and appearing perfectly healthy may be planted in the garden, field or greenhouse and the disease at that stage may suddenly become actively parasitic and quickly kill the plant without permitting further growth. The most common development of the disease occurs in the plants that are ripening their first fruits. At that period the plant draws heavily on the root and conducting systems for water. A cross-section of the main stem of the plant will show the darkened water tubes.

After the lower leaves yellow and die,those further up the vine are attacked and they in turn wilt, turn yellow and die. In the final stage the entire plant dries up. (18).

A condition which was noticeable in Porto Rico was that in the early field stages of the disease, wilting occured during the hot part of the day and the plants recovered at night (due in part to the lower temperature). As the disease progressed, however, the plants entirely collapsed.

After the plant has died, an irregular mildew-like growth of pinkish color often appears on the stem, usually near the ground. This is the spore mass or fruiting stage of the fungus.

This formation is usually found where the disease occurs in greenhouses. (18)

In attacking the roots of the tomato plant, Fusarium lycopersici causes a decay which appears to begin at the ends of the smaller roots at a considerable depth in the soil and gradually works up into the tap-root. Byrd (4) in his seedling studies at Illinois has not found a case in which infection occurs thru the root hairs. Root rot of tomatoes is often a symptom of attack by F. lycopersici and in advanced stages the root system may be entirely dead. (18). The writer has observed in his tests at Illinois that dwarfed plants (a marked characteristic of transplants which are seriously attacked by the disease) have a greatly restricted root system, much of it apparently rotting away.

Edgerton (10a) shows a picture of a tomato fruit which has developed a discoloration of its fibro-vascular bundles, as a result of its infection by wilt. He says "occasionally the black fibro-vascular bundles (from the stems) pass into the young developing fruits". The Connecticut Station (7) reports that Fusarium lycopersici was found on much cracked fruit in 1890. The description of the fungus was brief--merely that a mould-like covering white at first and later pink, was produced. It is very improbable that this disease corresponds with the one which is under discussion. (The disease was probably Fusarium solani).

A brief Summary of the Symptoms (18) follows:

(1) Yellow lower leaves, showing no localized spots.

(2) Stunted growth, especially in young plants.

(3) Discolored stem.

(4) Veins and woody tissue of the stem when seen

in cross-section have a dark brown color (traced from root to stem)

(5) In advanced cases the stems turn brown on the outside in irregular lesions (starting usually at some leaf base).

(6) Pinkish spore mass on the stem near the ground.

(7) Partial or complete rot of the root syatem.

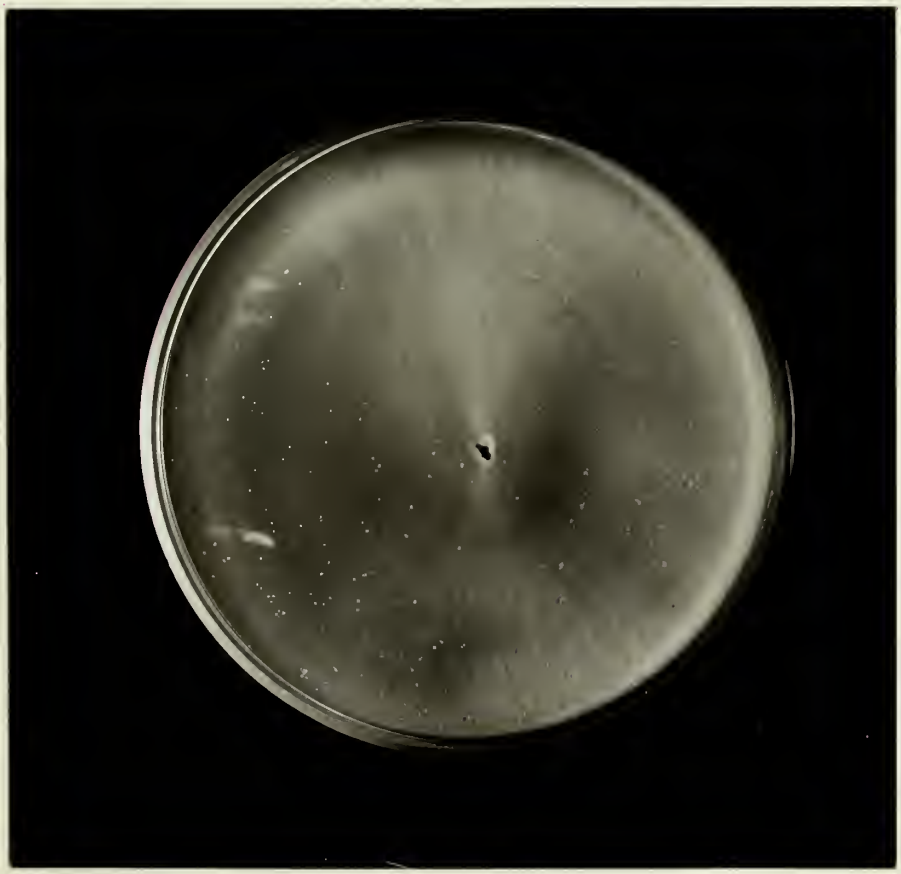
Comparisons with Bacterial wilt and other Wilt Diseases.

Because the symptoms of bacterial wilt, fusarium wilt,summer blight and yellow blight are very similar in a general way, comparisons will be drawn which permit of a close distinction between these tomato diseases.

As fusarium and bacterial wilts are the most widespread in this country, the two will be contrasted first. As a rule Fusarium lycopersici causes a gradual death of the plant. A partially resistant plant may persist for a number of days and one bred for resistance may live for several weeks after susceptible varieties have perished from the disease. (10a). Even with susceptible plants the growth of the fungus in the vascular system is comparatively gradual, the lower leaves succombing first and later the whole plant collapsing. With bacterial wilt, on the other hand, there is no recovery of the plant over night (as has been noted with fusarium wilt) but a very rapid and complete wilting and death of the plant. (31b).

The second distinction lies in the fact that when the stem of a tomato damaged by bacterial wilt is cut across, the stem will exude a dirty,milky slime (containing bacteria). This symptom is characteriastic of bacterial wilt only. (18). Examniation under the microscope is always the best way to make sure of any disease in question. In the case of Fusarium lycopersici strands of the mycelium will be seen stretching across the large circular ducts

A PURE CULTURE OF FUSARIUM LYCOPERSICI
on tomato agar. Made March 3 1921.
Note aerial mycelium.



A PURE CULTURE OF FUSARIUM LYCOPERSICI
ON CORN MEAL AGAR. Made Feb. 22 1921.
Aerial growth lacking.

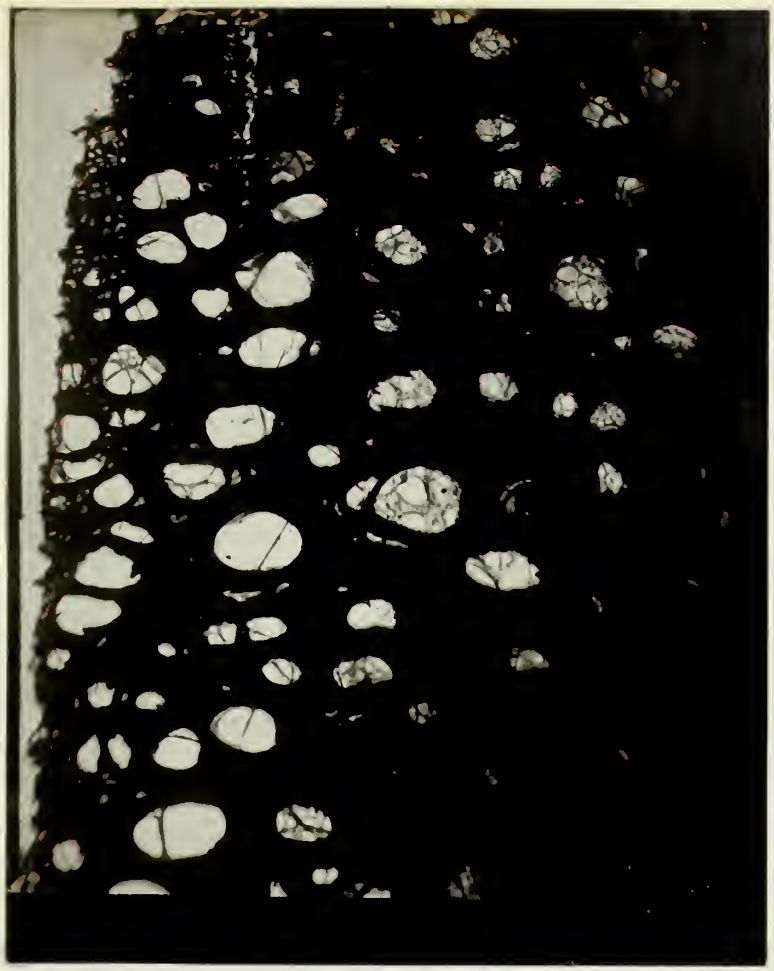
of the fibro-vascular system. If the wilt is due to bacteria, groups of microscopic rod-shaped organisms will be found in the vascular systems of the plant.

Another contrast between fusarial and bacterial wilts lies in the mode of infection. Fusarium lycopersici is a soil disease and enters the tomato thru the roots. Bacillus solanacearum, the causal organism of bacterial wilt, is carried from infected to healthy plants by biting insects, by pruning knives and cultivating tools. For this reason bacterial wilt usually occurs in more localllized areas and is spread less rapidly than fusarium wilt.(31)

Summer Blight and Yellow Blight are fusarium diseases which attack only the roots of the tomato, bringing about the death of the plant by the gradual killing of the root system. Humphrey (19) discusses the yellow blight disease of the Northwest. He says that two species of fusaria have been found associated with this disease; namely, F.orthoceras and F. oxysporum (the latter also causes the wilt of Irish potatoes). "Yellow Blight does not darken the fibro-vascular system of tomato stems as does the F. lycopersici.

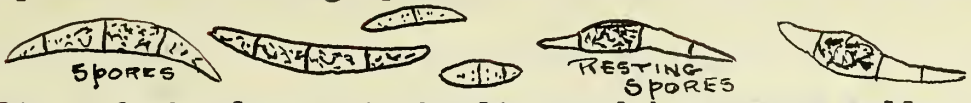
III. CAUSAL ORGANISM.

Description--Fusarium lycopersici belongs to the Fungi Imperfecti Order of Hyphomycetes. The family name is Tuberculariaceae which contains the genus Fusarium and the species lycopersici. The conidia of the genus are spindle-shaped, curved and several celled when mature. In F.lycopersici the conidia are falcate, acute and measure 25-30 microns by 3.5-4 microns. They are hyaline to yellowish. Conidia of two kinds are produced; namely Fusarium (macroconidia) and Diplocladium (microconidia). Infection is subterranean. Chlamodospores are produced.



A micro-photograph of a cross section stem of a tomato showing mycelium of the wilt fungus in the vascular system. Specimen secured from an Urbana garden 10-26-20.

Pure Cultures of Fusarium lycopersici, the two on the left(prune agar) from Berkely Cal. The one on the right on corn meal agar made in Urbana Ill. (Photo 1921)

Typical spores and resting spores are shown in the accompanying sketch. 

The mycelium of the fungus is hyaline and has cross walls. (32)

In our work the response of the fungus in pure culture has been as follows: apple agar--growth slow, oat agar--growth rapid, corn meal agar--slow to medium, tomato agar--very rapid, potato agar--rapid, and prune agar--very rapid. In the case of tomato, potato and prune agars a large amount of aerial mycelium was produced by the fungus, while in the other cases the mycelium vegetated almost entirely within the agar itself.

Temperature Relations--Clayton (6) in experiments at the Wisconsin Station reported that petri-dish cultures exposed to temperatures ranging from 8 to 38 degreesC. for nine days showed ~~showed~~ that the optimum temperature for growth is 28 C. He found the minimum to be 9-10 C. and the maximum 37 C. Abundant growth however, occured between 18 and 31 C. The optimum soil temperature for the normal tomato plant was found to lie between 25 and 30 degrees C.the maximum being a little above 35 and the minimum a little below 12 C. Tomatoes grown in soil infected with pure cultures of F. lycopersici were subjected to soil temperatures ranging from 19 to 35 degrees C. The optimum soil temperature for the development of the disease proved to be about 28. The disease rarely appeared at temperatures lower than 22 or higher than 32 C. Edgerton (10a) places the optimum temperature for growth of the fungus at 29 degrees C. As his lowest experimental temperature was 14 he did not determine the minimum. His maximum was set at slightly above 37.5 C. Tests showed that while the soil temperature is around the point of optimum growth for the fungus, the infection runs from 85 to 98% but in these

trials in which the soil temperature was below this, the infection percentage was very low. A plotted curve of growth of the cotton wilt fungus (F. vasinfectum) was found to be almost identical with the curve as drawn for F. lycopersici, but the cabbage yellows (F. conglutinans) showed a slower growth at all temperatures; namely, 14 to 37.5 degrees C.

Length of Life in the Soil --Humbert (18) claims that a 4-year rotation is not long enough in some types of soil, meaning, of course, that the fungus is serious on fields where tomatoes have followed tomatoes during periods of 4 years or less.

The fungus (23) forms resting spores (chlamydospores) in the soil and thus keeps itself alive from one season to the next. It seems capable of continuing this process in the soil without the tomato plants being present.

Edgerton (10a) says "there is no doubt but that Fusarium lycopersici will live for a period of three years or more in the soil, yet a three year rotation will eliminate the disease to such an extent that the actual loss in the field is small". In this respect the wilt of tomatoes is different from the wilts of such plants as cotton and cabbage where the organism lives in the soil for periods varying from 7 to 15 years.

"Because a field develops tomato wilt after being in other crops for a number of years does not mean that the fungus remained alive in the soil during all that period. There are many ways in which the disease could be brought into a field, such as the wash from other fields, the carrying of spores by the wind, and the setting out of young plants which are already infected with the fusarium wilt" (10a).

Comparison with other Fusaria. The following table is by Cromwell. (8).

SPECIES	SCLEROTIA	SPORODOCHIA	PINNOTES	CHLAMYDOSPORES terminal.
F. lycoper.	Flesh color	Numerous	Perfect	Intercalary
F.oxysporum	Green and Flesh color	Few	Reduced	Intercalary,terminal 6 to 12 microns.
F.vasinfectum	do	Numerous	Perfect	Intercalary,terminal
F.niveum	Large green	do	Reduced	Same as F. lyco.
F.tracheiphilum	Green and flesh color	Few	None	Intercalary,terminal
F.discolor	None	Numerous	Perfect	Intercalary.

The wilt disease parasites differ (40) from each other, Cabbage wilt is distinguished by the absence of sporodochia and sclerotia; cowpea wilt has blue sclerotia; tomato wilt has colorless sclerotia. Some of them produce a pinnotes stage very freely as cotton and tomato wilt. This is entirely wanting in cowpea wilt. The average diameter of the conidia masses have also been found to be variable within the Section Elegans.

The differences of the wilt disease parasites confirm the fact that we have to do with different species and varieties. The parasite of one host, as a rule, has not been found on the living organs of another host. In pure culture the parasite from one host did not cause wilt in any other host as a result of inoculation experiments. Thus at least 10 wilt parasites can be easily distinguished by means of pure cultures. Some of the most widely divergent wilt fungi are Fusarium lycopersici and F. vasinfectum, also F. conglutinans and F. oxysporum. (40).

The Georgia Station has shown (20) that peppers and egg-plants can be grown on soil badly diseased with F. lycopersici and recieve absolutely no infection. Tests at Illinois have also shown that Irish potatoes are immune to the disease. 1921.

The writer inoculated the soil in which the potatoes were grown ~~heavily~~ with a pure culture of F. lycopersici.

Harter (16) reports that the belief prevailed in some parts of Maryland that tomatoes following sweet potatoes infected with stem-rot would contract the disease from the potatoes. This supposition was based on the idea that the two organisms, F. hyperoxysporum and F. lycopersici were the same. By means of pure cultures, Harter showed that F. hyperoxysporum would not attack tomatoes and that F. lycopersici would not attack the sweet poatato. Cultures of each were effective on their usual host plants.

Laboratory and Greehouse Experiments--The first test which will be discussed was a study of the resistant qualities of certain varieties of tomatoes to fusarium wilt. As far as possible these tomatoes were given identical treatment thruout the experiment.

Two plants of each of the following varieties, Prolific, Sutton's Best of All, Marvel, Norton, No.324, P.R.443, and Diener were used to test the varieties on diseased soil. Seed was sown on a clean 4-2-1 soil (4 parts soil,2 parts rotted manure, 1 part sand) Sept. 23, 1920 and at the first transplanting (Oct.12) the young plants were set in flats the soil of which had been thoroly infected with F. Lycopersici thru the medium of diseased stems. On Oct.25 the plants were shifted to 4-inch pots and at that time no disease was showing in any of the varieties. Five days later two plants of each variety were transplanted to large cylindrical crocks 12 inches deep and 12 inches in diameter (see photo). There was a half inch hole in the bottom of each crock to facilitate drainage.

The lower half of each crock was filled with a mixture of two-thirds Illinois black silt loam and one-third gravel, the upper half of the soil was a 4-2-1-mixture. (This mixture was used thruout our experiments unless there is statement to the contrary.)

The first variety to succomb (1month 4 days) to fusarium wilt was one of the"Prolific" tomatoes. On Nov.16 the lower leaves of the plant turned yellow and later dropped off. The growth of the plant practically ceased at this point. It took on a sickly appearance and a portion of the stem near the ground turned water-soaked. Later this condition extended half-way up the stem which finally became shrunken and dried. Leaves further up the stem wilted, turned yellow, died and fell to the ground. Finally only a tuft of green leaves remained at the top. By Nov.25 the plant had fallen over in the crock--the final stage. The height of the diseased plant when it dropped was 8 inches. An average of the others on the same day measured 24 inches. The time from trans-planting the tomatoes on diseased soil until complete death was one and one-half months.

On the days following the collapse of the plant just mentioned, another plant of the same variety grown heretofore on clean soil was set in the crock containing the diseased soil. It was not until Jan.10 that the first signs of the wilt appeared on this plant. The lower leaves turned yellow and an examination of the vascular bundles showed them to be darkened. Because of the cooler greenhouse conditions and the darker days of mid-winter, this slower infection was anticipated.

One other"Prolific" plant (a dwarf reversion) which was set in the crock Oct.29 also,did not die from the attacks of the disease until Dec.20. It was somewhat later than the plant first

mentioned, in contracting the disease and lived 25 days longer. This result is in keeping with the work of other investigators who have found that the dwarf types are, as a class, more resistant to fusarium wilt than are the standard commercial varieties.

P. R. 443: On Dec.14 there was no sign of the disease and both plants were very vigorous (probably best of varieties). On Jan.26 one plant showed slight symptoms of wilt. A few lower leaves yellowed and dropped from the plant. The disease, however, did not reach an advanced stage. The other plant appeared entirely resistant until removed. From this it might appear that the variety was very resistant. These tests are not comprehensive enough as will be shown later in the article.

Norton: One plant succombed to the disease. First signs appeared on Dec.6 when the lower 4or 5 leaves yellowed and dropped. Leaves higher up began to wilt and on Dec.30 the plant was dead. A picture of this plant is shown, together with one plant each of the varieties"Marvel" and "Prolific". The other Norton plant did not take the disease. A comparison between the diseased Norton and the vigorous Marvel (see picture) is worth studying. The Norton tomato succombing to the disease was certainly lacking in the quality of resistance.

Best of All::One of the two plants set in the crocks had taken the fusarium wilt quite badly on Jan.20. Several leaves in a straight line for,perhaps two-thirds of the distance up the main stem had yellowed and died. Whereas other parts of the plant seemed unaffected. This peculiar incident haalso been noticed at various times by Byrd (4). The fungus in its progress up the stem of the plant may cause wilt and disease to all the leaves in the direct path of a fibro-vascular duct. If bundles in other sections

Two tomatoes of the same age, both on diseased soil. One diseased, the other not. Note dwarfing effect of wilt.

THREE TOMATO PLANTS OF THE SAME AGE SHOWING THE EFFECTS OF WILT. (All on diseased soil) The Marvel is resistant and the Prolific very susceptible.

of the main stem are not affected the leaves which are adjacent to the diseased bundle are not injured. They may remain unaffected for a considerable period of time. As 9 fruits were set on this plant, the condition was more favorable for a rapid spread of the disease. On Feb.2 eleven of the fifteen leaves on the plant showed some disease. By Feb.7 the eleven leaves were (with 2or3 exceptions) dead and a tuft of 4 at the top had become affected. Complete death resulted a few days later.

Marvel One plant (see photo) was completely resistant to wilt. The other showed first symptoms Jan20. The disease was not serious at that time as only the lower leaves were affected. By Jan.26, the plant had contracted the disease along its entire length. Leaves at intervals were wilting and partially yellowed. The petioles of some of the leaves were badly streaked (externally), black and withered on one side causing the leaf to droop down. This instance demonstrates that so-called resistant plants are not entirely so, but succomb to the wilt disease in time. Note the late infection in this case.

No 324: One plant appeared to be entirely resistant to wilt. The other plant showed characters, which if studied out carefully, would probably give a comprehensive explanation of the resistance quality in tomatoes. On Dec.1 the disease was first noticed as the foliage was wilting and a portion of the stem near the ground appeared water-soaked. By Dec.6, practically all the large leaves were wilting. Observations Dec.30 showed that the plant had revived and started to push up a spindling growth. No leaves were wilting at this time, tho several of the lower leaves, formerly yellow, had dropped to the ground. By Jan11, a few more of the leaves had dropped. When all the varieties were removed from the crocks,

Feb.19, the upper part of the plant was largely dead.

Diener: Both plants were apparently resistant in these tests. The other characters (as vine and fruit) of the tomato were far inferior to any variety in the test. The writer believes it should be dropped from further consideration.

Trials were also made on the large crocks of diseased soil, to determine the percentage resistance of the varieties, Marvel, 324, and Norton, as compared with susceptible types such as Baer, Earliana, and Beauty. 125 seeds each of a resistant and a susceptible variety was sown in half the soil of each crock respectively. Though the soil was positively diseased,(having grown plants killed by fusarium) only negative results were secured. It is probable that the disease was not virulent enough and the temperatures were too low for its optimum growth. Sterile soil and a pure culture of the fungus should have been used. A method suggested by Edgerton (10d)of placing sterile inoculated bean pods carrying F.lycopersici, into stelelized soil in pots and planting the seed on this was also tried. Normal soil was also used for checking purposes. Here again results were only negative. In this case a dark period of 9-10 days followed the germination of the seed and temperature conditions were also unfavorable (Jan.)

ROOT PRUNING TESTS. The commercial grower in producing his tomato plants, sometimes grows the plants in hotbeds. The seed is sown directly in the hotbed soil and the plants may stand there until ready for the field or they may be transplanted to other hotbeds or coldframes spacing the plants 3or 4 inches apart. In removing the plants to the field large numbers of fibrous roots are broken off. With these ideas in view, tests were started (Feb.18 1921) on root pruning to determine whether or not injury

to the roots facilitates the entrance of the fungus Fusarium lycopersici; and if so,to what extent ~~does~~ the damage occurs. The varieties for the first tests were "John Baer" and "Beauty", susceptibles, and the"Imperial", a resistant. In all of these trials,the seed was sown and the plants grown in clean soil until the plants were transferred to 4 or 6 inch pots as the case might be. At the time of the last transplanting, about one-third of the massed fibrous roots growing next to the inside of the pot were cut off and a pure culture of F.lycopersici,contained in the agar of one petri dish, was used to inoculate the injured roots at the time the plant was shifted.

Two plants each of "Baer, Beauty, and Imperial"were used in the initial experiment. Unfortunately the "roots pruned" and " "roots not pruned", plants of Imperial and Beauty, contracted the mosaic disease. This, of course, introduced another factor which tended to give ~~us~~ negative results in the work on wilt. All of the plants under test eventually took the wilt disease. By Mar.30 the disease was more or less prevalent but worse on the varieties Baer and Beauty than on the Imperial. Generally speaking, the results obtained were too doubtful to be recorded as data of real significance.

Realizing the value of tests of this nature, the writer instituted an experiment on a larger scale than the above. The treatment was similar to the first tests, clean (4-2-1) soil being used at all times. Inoculation was done at the time of the last transplanting. In addition to two plants,"roots pruned" and two plants,"roots not pruned", a check plant of each variety on which no fungus was used, served for comparison purposes. The varieties were"Norton"and"Marvel",(resistants) and"Earliana"and"Beauty",

(susceptibles). The first transplanting was done March 22, so that the seed must have been sown some two weeks previous. The disease was applied in pure culture form to four plants of each variety,which were shifted, two to 4-inch pots and two to 6-inch pots (also one check to 4-inch pot) on April7. Later, on April 26, the three plants of each variety growing in 4-inch pots were shifted to clean soil in six inch pots. Among other things, it was observed that the plants which were shifted to 4-inch pots and later to 6-inch pots never reached the size of the plants which were transplanted directly from the 2 and half inch pots to the 6-inch pots. Consequently it appears that the former were checked in the 4-inch pots, as a result of wilt, a root bound condition or perhaps both. One of the first symptoms of wilt in these experiments was a dwarfing of the plants.

On April 26, first signs of the wilt disease appeared. It is significant to note that in each case the disease appeared only on plants which had been root pruned. Both susceptible varieties, Earliana and Beauty, showed symptoms of injury at this time. One Earliana plant had two of its large upper leaves diseased. The plant also appeared dwarfed and with restricted root system. This plant had been set previously in a 4-inch pot. The other "root pruned" (from 2 to 6-inch direct) showed no signs of wilt. Both plants of Earliana "roots not pruned" showed no disease on Apr 26.

In the case of the "Beauty" (shifted 2-4-6-) "roots pruned" a large yellow lower leaf was diseased and the whole plant somewhat dwarfed. The other "root pruned" (shifted 2-6 pot) appeared to be slightly dwarfed and the lower leaves of a light green color April26. Both plants of "roots not pruned" had no signs of wilt at that time.

One plant of the resistant Norton tomato (shifted 2-4-6) had one lower leaf yellowed and apparently diseased. The other three Norton plants and the four Marvel tomatoes showed no signs of disease Apr.26. The check plants of each variety were vigorous, presenting quite a contrast to some of the diseased plants which had become stunted.

All four plants of Earliana showed the disease badly on May3. The worst diseased plant was "roots pruned" (2-4-6). Only a tuft of leaves at the top and one lower leaf were alive at this time. The next most badly diseased was"roots not pruned"(2-4-6), 4 leaves and the tuft at the top remained. Both of these plants were badly dwarfed and not over half the height of the check plant. Of the 2-6 pot shift, the roots pruned had the lower 4 leaves badly diseased while the "not pruned" had only the lower 2 leaves diseased. On May 11 both of the 2-4-6 Earlianas were practically dead except for the growing tuft of leaves. The lower leaves of the 2-6 plants were dead on the same date while the check was uninjured.

The"Beauty" variety, which proved the most susceptible of the four tested, appeared as follows: (May 3)

1--Roots pruned (2-4-6) all leaves diseased except upper 4& tuft.
2--Roots not pruned " " " " " " 5" "
3--Roots pruned (2-6) " " " " " 4" "
4--Roots not pruned " " " " " " 6" "

While the differences in each of these cases were not great it can be seen that what advantage there was lay with the" roots not pruned" tomatoes in each case.

By May 13 all plants of the Beauty variety were dead except the check. The plants were further gone than any of the others.

The Norton variety (2-4-6-) roots pruned showed advanced signs of wilt May 6. The two lower leaves turned yellow and the plant was stunted. The roots pruned 2-6 also showed wilt at this time as the three lower leaves were yellowed. Aside from these two cases there were no external symptoms of wilt on any of the plants. The stems of the 4 inoculated plants were sectioned May 13 and three of them showed blackened bundles. This, of course, showed that the disease was present in the plants. The check showed no wilt.

The Marvel tomato was the most resistant of the varieties under test, as evidenced by the fact that there were no symptoms of wilt present as late as May 3. By May 11 on the lower leaf of each of the 2-4-6 roots not pruned and 2-6 roots pruned, a yellowing had occured. Examination of the sectioned stems May 13 showed that only one plant (2-4-6) roots pruned, had even the slightest indication of blackened bundles. This small area was on one side near the base of the stem.

These tests have shown that root pruning not only permits of an earlier entrance of the fungus;but also,brings about a more rapid death of the tomato. In the light of present practise among tomato growers in America, this data may be of value, especially to the producers of early crops in the warmer regions of the country. The value of early tomatoes being proportionally high, tomatoes may be grown always in pots and shifted directly to the field. Root pruning checks the growth of any plant (tomatoes or otherwise) and a weakening of the plant facilitates the entrance of disease. By using pots for producing tomato plants, root injury is practically eliminated.

ROOT PRUNING TEST. Marvel (on left) a resistant and Beauty (on right) a susceptible variety. All plants except the check treated with Fusarium lycopersici (pure culture).

ROOT PRUNING TEST. Norton (on left) a resistant and Earliana (on right) a susceptible variety. All plants except the check treated with Fusarium lycopersici (pure culture).

Two illustrations (taken May 4),accompanying this discussion, show clearly the differences which exist between tomatoes which have been root pruned and not root pruned, when inoculated with a pure culture of Fusarium lycopersici. Note the difference between the plants of the variety"Beauty". The "roots pruned" plant is in an advanced stage of wilt, practically all the large leaves are dead or wilting. The "roots not pruned", on the other hand, is still comparatively vigorous (except for a few of the lower leaves) and has little wilting. The check plant is shown for contrast. The two Marvel plants shown in the picture have both been inoculated but show no signs of wilt.

Compare the"roots pruned" with the "roots not pruned" Earliana tomatoes. It is evident that a majority of the lower leaves of the former are gone while the corresponding leaves in the latter are still in fair condition. Those on the "roots not pruned" are wilting but have not dropped from the plants as have the leaves on the tomato "roots pruned".

For comparison the only dwarfed plant of"Norton" is shown. While the lower leaves showed no yellowing at this time, the general condition of the plant indicated wilt. This was later proven by both external and internal behavior. This again proves that the so-called resistant varieties of tomatoes possess individuals which are lacking seriously in the matter of power for resistance.

IV CONTROL METHODS

Crop Rotation and Sanitary Measures.--Wollenwebber (40) notes that "besides the wilt-resistant strains of tomatoes, cotton, watermelons,etc, attention to the matter of crop rotation has,independent of science, worked successfully on the control

problem. It has been found by long experiance that cotton and cereals grow well after potatoes, after which, of course, other vegetables requiring intercultivation, such as beets, cabbage, and turnips may follow. Successful practise has shown that the more widely divergent hosts are,the shorter will be the period of rotation required. The fusaria of the tomato and Irish potato wilts seem to differ so widely that one may be easily inclined to recommend the growing of these crops in continuous rotation unless other factors stand in the way, such as one sided exhaustion from related solanum species or different climatic adaptations."

Edgerton claims (10a) that a period of 3 to 4 years should be allowed to elapse between crops of tomatoes in fields affected with wilt. Under these conditions, it is stated that subsequent loss will be small. "Because wilt appears in considerable amount after a three year rotation does not mean that the disease has been carried in the soil of that field over the period. There are various agencies which may serve to carry the disease both to old and new points of infection; such as implements, feet of workers, or work animals (carrying soil particles),drainage water (from one field to another), old tomato stakes, and by means of diseased seed."

Sanitary measures which are largely effective in controlling fusarium wilt may be classed as preventive in nature. In the first place clean seed should be planted. In case of any doubt regarding the seed, it should be disinfected by soaking for 15 minutes in a formalin solution (using one teaspoonful-40% sol. to the teacup of water). The seed should then be washed in clear water and dried.

Seed Bed Sanitation--"Particular care must be used to keep

the disease out of the seed beds, because if the plants are attacked before they are set in the field, there is small chance of maturing a crop. Healthy plants set in a diseased field have a much better chance of maturing a crop, than do plants already diseased set under the same conditions. On farms where the disease has made its appearance, the use of old soil from year to year should not be permitted in the seed bed. In securing new soil for such a bed it must be certain that the soil when it is used has not become infested by wash from diseased fields or thru some other source". (10a).

The old soil may be used for seed beds providing it is steam sterelized. The value of steam sterilization for controlling F.lycopersici was demonstrated on the commercial crop grown by the University of Illinois during the spring of 1921. The soil of two benches was steam sterilized except for a small area (large enough for 16 plants in each case) at the opposite ends of each bench. In one case 8 of the plants grown on untreated soil were very badly diseased with fusarium wilt at a time when tomatoes on sterilized soil were largly unaffected. In the other case of 16 plants on untreated soil, several of these were also dead or dying as a result of the wilt. During the peak of production for the average of the plants, the diseased tomatoes were, for the most, part, dead.

Formalin drench (10a) is not effective in killing the disease in the soil, however it is a good precaution to disinfect the frames and woodwork with formalin.

The practise which some growers have of buying their plants from outside often leads to serious results. This has been evidenced in the case of Gibson County Tennessee, (11)

a locality which recieved its tomato plants from Florida previous to 1912. These plants were diseased with fusarium wilt and as a result introduced the malady into an entirely new district. The disease then spread so rapidly that it threatened the entire tomato industry of the state.

Lastly, sanitation should be practisdd in the field. As soon as the disease appears on plants (in locallized areas), they should be pulled and burned. After a crop has matured the dead vines, if diseased, should be destroyed. If the diseased tomatoes have been staked, the stakes should be dipped in a formalin solution, before using them in new localities the following year.

Use of Wilt resistant Varieties

Practical value of Wilt-resistant varieties-"The "Acme" strain of tomatoes as selected by Edgerton in Louisiana has proven to be very resistant or immune to the disease as tested under Ohio conditions" (18). This selection also showed high resistance to Septoria and to Alternaria leaf diseases. The "Beauty" strains from Tennessee proved to be highly resistant to fusarium wilt under tests at Marietta and Wooster Ohio in 1917, altho tests of the preceding years were not especially promising. This tomato has a comparatively high yielding ability, is quite early and has a good resistance to the disease". (18).

In 1916 tests were made at the Louisiana Station (10a), which included 5 varieties; two were resistant ("Globe and Dwarf Stone"); two that were very susceptible ("Acme and Stone"); and one early fruiting susceptible variety, "Earliana". These varieties were planted in two different fields, one of which was badly infested with Fusarium lycopersici, and another which was free of the disease, never having grown tomatoes before. The wilt percent-

age in the Stone and Acme varieties was much greater than in the Globe and Dwarf Stone. The yields were as follows: Globe- 15090 pounds per acre, Dwarf Stone 7550 pounds, Stone 790 pounds, the Acme- 950, and the Earliana 10670,pounds per acre. The Earliana showed less wilt than the susceptible varieties but considerably more than the resistant ones.

Norton (21b) in 1912, tested out on wilt infested soil on the eastern shore of Maryland, a large number of tomato varieties. This investigation showed quite certain differences in resistance among the varieties, but none of those generally suited for canning were found to show any decidèd freedom from the disease. Aside from the "Buckeye State,Faultless,Golden Ball,Golden Queen, Dwarf Stone and the Globe, which showed decidly less disease than the others, the small fruitèd types were found to be more or less resistant as a class".

"During the fall of 1912 the best plants were selected from the worst infected fields of the usual canning varieties in order to find a resistant strain of a good canning tomato. The seed from a number of good plants from different eastern shore fields were planted on the infected soil in 1913 and while some of them proved no better than the usual strains, several showed decided vigor and healthfulness in their offspring."

After tests of three years, during which time the resistant quality was passed on from generation to generation, two valuable strains; namely the"Greater Baltimore", and the "Selected Stone" were developed. In 1917 the Bureau of Plant Industry at Washington D.C. grew 70 pounds of a very fine Stone type from one of the Norton selections. A grower who was producing seed of the resistant greater Baltimore tomato found that the selection

yielded a 90% crop whereas the ordinary greater Baltimore stock gave only a 25% crop beside it. These selections were not resistant to bacterial wilt or leaf spot.

Temple (36) states that during the year 1918 two wilt resistants, one from the Stone and the other from Greater Baltimore were propogated extensively, and about a thousand acres of the two varieties were planted in Maryland. In Dorchester County the county agent reported on 67 tests an increase of from 10 to 400%in favor of the wilt-resistant over commercial varieties, which were used as checks. In Caroline County 17 tests gave a yield of three and a half tons per acre from the commercial varieties and four and one-tenth tons from the wilt-resistants in the same field. This is an increase of 36 five-eights bushel baskets to the acre due entirely to the seed. Out of 167 tests in 1918 only three reported a decrease in yield due to wilt resistant seed and only eight reported the wilt resistant as low in yield as the commercial seed. On the other hand, fourteen of the best results taken from these reports gave an average increase of 99 five-eights bu. baskets per acre.

Norton (21a) writes that the resistant Greater Baltimore seems to be otherwise exactly like the ordinary Greater Baltimore and is the highest in yield of all the canning tomatoes grown in Maryland. A quantity of the seed of this resistant variety is being grown commercially by several farmers in Maryland. The variety "Red Cross", listed by the Bolgiana seedsmen of Washington D. C. was secured from the Greater Baltimore selectinns. No recent selections have been made by Norton since developing the resistant strains of Stone and Greater Baltimore. The variety "Norton" developed by Fred J. Pritchard of the U.S.D.A. is a selection from Norton's best strain of the Stone type. This variety is also

grown extensively in Maryland and with great success on infected land. There is some complaint that it does not produce as heavily as Stone but many get even higher yields from it. Pritchard's "Arlington" and "Columbia" have been developed from Norton's Greater Baltimore selections.

Washington Wilt-resistant Tomatoes. Pritchard (26) describes the U.S.D.A. varieties as follows:"the "Marvel" is a medium early variety which, under favorable conditions, produces a large crop of medium sized fruit which is red, smooth and of fine flavor. It is suitable for forcing, for gardening and for trucking. "Norton" and"No.324" produce a heavy crop of large, smooth, red, solid, (flat) fruit. They are typical canning varieties and should not be grown in the greenhouse as the vines are too large and dense for such use."

A short time ago the seed of the "Arlington"variety was accidentally crossed so that the seed of this variety is not being distributed until there is opportunity to improve the stock. The Arlington is said to be a little more resistant than the Columbia, otherwise the two are very much alike. The origin of these two varieties has already been mentioned.

Resistant varieties of tomatoes developed by the U.S.Dept. of Agriculture are reported to grow vigorously in Florida." The co-operative tests conducted by the Bureau of Plant Industry have shown that in 24 states (including the southern Gulf States) that the Washington resistant varieties possess remarkable resistance to the wilt and are as good as the best commercial varieties in yield and quality of fruit even when grown on wilt free land" (26).

At Washington D.C. (26) a cross has been made between the "Marvel" and the"Earliana" tomatoes. Third generation strains were

grown and selected during the 1920 season. One of these appeared very promising, as it was as early as the"Earliana" and produced a heavy crop of excellent fruit. There is no certainty,however, that it will continue to produce uniformly smooth fruit. It will probably be 2or 3 years at least before seed of the cross will be distributed.

Rosa (27) of Missouri states that five of the Washington wilt resistant varieties have been grown at Columbia for two years and all of them have been found to possess resistance to a high degree. However, the varieties were criticized because of their"poor type of fruit." All of them were described as being "flat and rather rough in shape, with abnormally large core and a scar on the blossom end. These defects could be overcome by proper selection". The yields of the Washington varieties under field conditions in Missouri were found to be as follows: Norton, first, Arlington and Columbia about the same, but somewhat inferior, and the Marvel ranking poorest."The Marvel seems to be considered earlier than the other varieties. In its present condition it is a poor yielder and has a poor type of fruit".

The "Marvel" has been tried in Maryland (21a) and was found to be quite resistant. Norton did not know enough about its commercial characters to say whether or not it could be grown with profit in Maryland. As already pointed out the "Norton" tomato is grown with great success on the Peninsula.

The wilt-resistant strains developed by the U.S.D.A. and the Maryland Experiment Station gave excellent results in Maryland (38a) in 1920. It was said that this method of combatting the disease was the most practicable and the cheapest method that that could possibly be devised."Some growers have a mistaken idea

that wilt resistant tomatoes are also resistant to other diseases."

Field tests (20) with the wilt resistant tomato seed from various sources at the Georgia Station in 1919 showed that no strain was sufficiently resistant to grow thruout the summer on heavily infected soil. This is to be expected when one considers that the tomato plant is "tolerant" to the fusarium in its vascular system and not totally resistant or immune to the disease.

Edgerton (10a) found that the U.S.D.A. resistant varieties, Norton, Marvel, Arlington, and Columbia were a week to ten days later in extensive variety trials, than such earlies as Earliana and June Pink. Louisiana selections were intermediate. There was a decline in susceptible varieties after the third week, while the decline with the resistant varieties did not come until after the fourth week. (See tables 7, 8, and 9 La. Bul. 174).

"Under Louisiana conditions resistant varieties are not usually very prolific tho on badly infected soil they usually outyield most of the susceptible varieties."

Other points of interest brought out by Edgerton (10a) in this connection were that none of the varieties tested was really wilt resistant, as wilt was found in a large number of the plants of all the varieties when the stems were cut open and examined. However, the wilt does not develop as rapidly in some as in others. The varieties showed considerable variation in regard to the percentage of plants killed or injured before a satisfactory crop was made. The so-called wilt resistant varieties showed a small percentage injured on June 25 while the percentage of some of the others was high.

"The very early varieties, Earliana and June Pink, being

healthy when set in the field, made a part of a crop before the wilt had time to materially injure the plants. Had the seed for these tests been planted in diseased seed beds, the yields from Earliana and June Pink varieties would undoubtedly have dropped to a considerable extent. Plants of these varieties when taken from diseased seed beds almost invariably produce a very poor crop. As it was Earliana and June Pink gave the best yields in these particular trials."

"The wilt resistant varieties produced a fair crop of fruit tho they were not as prolific as varieties of the Earliana type. The two Louisiana resistant strains produced slightly more than those from other parts of the country. The "Globe" was the most resistant of the commercial varieties but it made a light crop of fruit. The "Stone" was the most susceptible and produced the poorest crop of fruit of any tested. This last statement agrees with reports from all over the state of Louisiana.

In Louisiana the tests in the field were conducted in such a manner as to eliminate, as far as possible, the effect of any slight variation in the soil. A row of each variety was planted and this order of planting duplicated four times, thus making 5 rows of each variety in different parts of the plot. The plants were all healthy when set in the field."

During the years 1916 to 1918, the Georgia Station (17) tested several varieties of wild tomatoes from Central and South America. These were planted to find out if they were resistant to Fusarium lycopersici, and if so to cross them on cultivated species. The Station report for 1919 indicated that no immune wild variety had been found which could be crossed with the cultivated species for bredding purposes. Higgins substantiated this in 1921.

NINE VARIETIES OF TOMATOES USED FOR

BREEDING STRAINS RESISTANT

TO FUSARIUM WILT.

(Note pollenating bags on plants
Nos. 3 and 4 from right)

V BREEDING FOR WILT RESISTANCE IN TOMATOES

The Problem--The title of this thesis", A Study of the Inheritance of Disease Resistance and Fruiting Qualities in the tomato",explains in a few words, the problem with which the writer has had to deal in his experiments. The feature most lacking in the work so far has been the matter of earliness. This factor is very important,especially in the South where the so-called wilt-resistant tomatoes do not have a long bearing period. It is true that most of the resistant strains bear longer than the common commercial sorts,yet Edgerton (10a) has conclusively shown that the Earliana when set in diseased soil along side of resistant varieties will outyield the resistant types by virtue of its earliness. This pre-supposes that all plants tested are unaffected with the disease when set in the field. One of the chief advantages of early tomato varieties over those maturing later is that the bulk of the fruit is set early when temperature conditions are less favorable for the spread of the disease.

There is another respect in which practically all of the present varieties and strains of wilt-resistant tomatoes are lacking. The fruit is generally flat and lacks uniformity of shape. The ideal fruit should,of course, be nearly globular,smooth and run true to type. We have hoped to develop these characters in the strains which have been produced. Here again, success is dependent upon the matter of time.

The factor for resistance can also be improved upon over a course of years. To sum up the factors involved in this problem, we have,earliness,shape of fruit, and degree of resistance in the plants for our chief objectives.

Previous Investigations--Unfortunately the scope of this paper does not permit of direct application of the works of other investigators in the field of Mendelism and certain other problems to be dealt with in the F_1 and subsequent generations. The parents and immediate crosses of several varieties of tomatoes are being tested for disease resistance but the plants will not get beyond the stage of producing small fruit. The characters of the F_1 fruit will, therefor be unknown.

Groth (15) observes that" in crosses of types possessing factors for broken centers with other types, the inheritance of the cell number in the F_1 fruit is similar except that another factor for cell number, a function of the respective factor for broken center becomes active in determining the cell number of the cross. The factor for the lower cell number seems to be dominant." These observations are of interest because of the fact that the Porto Rican tomato No.443,used in our crosses, possesses the factor of a broken center. In the six crosses illustrated under xenia, the broken centers were very evident. This was to be expected considering the the Porto Rican tomato was the female parent in each case.

Groth (15) explains that" reciprocal and duplicate crosses usually agree in the inheritance of all characters studied(in New Jersey); but they may differ greatly. Even fruits borne by plants raised from seed of one fruit, pollenated by pollen from a single flower may differ radically in the characters of size, shape and number. The size and shape of the F_1 fruits are the geometric means between the size and shape corresponding to these factors of the parents which were active in crossing". More attention should have been given to the matter of duplicate and

reciprocal crossing in our work.

Price and Drinkard (25) in crossing tomatoes have found that unit characters,or factors, behave as follows; 1--Shape, varieties having pear shaped fruit when crossed with round fruited sorts, produced 84% roundish fruit in the second generation and 16% bore pear shaped. The proportions approximate Mendels law of 75% dominants to 25% recessives. The factor for roundish-conic fruit was dominant over that for flattened fruit 73 to 27%.

2--Color,Red was found to be dominant in proportions approximating Mendels law, to both pink and yellow colored fruit.

3--Foliage,Normal leaved tomatoes are dominant over potato leaved types in similar mendelian proportions.

4--Stature,Normal stature was dominant over the dwarf in the exact proportion of 75 to 25%.

The application of Mendelism to the matter of disease resistance is explained by Orton (22b)."When disease resistant varieties are crossed with non-resistant types, the resulting offspring inherit resistance to a limited and varying extent. The disease resistance may behave as a unit character and be transmitted in Mendelian proportions; that is, in the F_2 one-fourth resistants to three-fourths susceptibles. Under these conditions resistance is recessive."

"The chances for success in breeding for disease resistance depend on (1) Nature of the parasite,(2) its degree of adaptation, to the host species,(3) the length of time it has been prevalent, (4) possibility of crossing the host with related resistant forms."

The following are some of the suggestions offered by Freeman (13) for the production of resistant plants,

1--Possibilities of selection,variation,mutation,etc ~~similar~~

are similar to those in other lines of plant breeding.

2--In all lines of selection and breeding for resistance, control of the field conditions is necessary.

3--The investigator must be able to produce an epidemic when it is desired.

4--The field must be under control similar to that of a laboratory.

5--In some cases a gradually increasing severity of the disease is sought for while in others a severe attack is desired from the first.

6--Disease-Enduring (as tomato wilt) A disease plot is indespensible where a gradual increasing severity of the disease attack makes possible the gradual elimination of undesirables.

7--Hybridization is valuable in varieties which are truly resistant but [or possibly] otherwise worthless are crossed with desirable varieties, no strain of which shows the slightest resistance.

8--Resistance must not only be established but must also be maintained, as possible variations or mutations of the disaase organism may arise."

Orton (22a) says" all plant breeding should take disease resistance into account. Strains under test should be exposed to infection by all the parasites that they are likely to meet in order to bring them into an equilibrium, for it is possible by breeding plants in the presence of their diseases to produce resistance varieties. Such resistance should be reasonably permanent, at least as long as the varieties are not crossed with non-resistant types."

From Babcock and Clausen (1) we learn that" hybridization offers the most promising field in the development of resistant varieties. Experiments on watermelons have given us an example of this sort. All watermelons appear to be very susceptible to wilt (Fusarium niveum). So recourse was had to an inedible form, of citrullus vulgaris, known as the citron, which is immune to wilt. From a cross between the citron and the "Eden" watermelon F_1 hybrids were secured which were described as of wonderful vigor and productiveness. As the fruits were intermediate in character, selections were made, and an F_2 generation raised which had extremely variable characters. Ten fruits which were resistant and of good quality were selected from this generation and reproduced from their seed on badly infected plots. From these, melons were grown which closely resembled the "Eden" parent and were resistant."

In the tomato (1) Norton found that wilt resistance is recessive to susceptibility. He also claimed that wilt resistant tomatoes produced in Tennessee were susceptible in Maryland. (There may have been slight differences but present evidence points to the fact that resistant tomatoes produced in one part of the country are also resistant similarly in other sections, see page 23). Other evidence to the contrary is presented by Rosa (27) who says that the"New Century"tomato developed at Illinois is highly resistant under Missouri conditions and Edgerton (10a) who finds that the resistant varieties produced by the U.S.D.A are practically as resistant as the strains, La. Red and Louisiana Pink produced at Baton Rouge La.

Stuckey (1) found that the cherry, pear, and currant tomatoes were immune to blossom-end-rot, a functional disease, and

when crossed with commercial varieties, they transmitted resistance as a dominant character. (35). Resistance to leaf blight in cantaloupes was found by Blinn to be inherited as a dominant character. Norton, when breeding for resistant varieties in combatting asparagus rust found that resistance was dominant in all the F_1 offspring in his crosses between the female plants of the rust susceptible American varieties and a rust resistant European asparagus. The resistance was somewhat variable but was fixed by selection in succeeding generations. The two factors, then, which are most important in producing resistant varieties are hybridization and subsequent selection. Selection alone is a powerful means of improving plants with respect to disease resistance when used either in variety tests or in the improvement of a single variety." (1)

In a paper read before the Physiological Division of the A.A.A.S.meetings held in Chicago (Dec.1920),Higgins expressed his ideas on the matters of hybridization and selection. He said that "mass selection from "partial" or semi-resistant plants is a waste of time. Hybridization, with individual records is the line of work which seems to offer the greatest promise of obtaining permanently resistant or immune varieties." (17).

Edgerton (10c) does not entirely agree with Higgins regarding mass selection. However, he does not consider that mass selection is as satisfactory as individual plant selection. In his work he uses both methods and a combination of both. A short accountof his method follows: Individual plant selection is used for several years until the characters are about as well fixed as possible. Then the entire patch is gone over and the most desirable plants marked. The seed is selected from these separately. Full notes

are taken on all the plants in regard to wilt etc. At the end of the season a few of the best are selected for individual planting but the rest are combined into groups of about equal merit. He says," I do mass selection for seed that is to be distributed about the state. My breeding work is continued each year with the best individual plants or the best group of plants."

Nature of Resistance Qualities in Plants--Disease resistance may be defined (1) as the ability a plant has to develop and function normally under conditions such that other plants of the same species fail to develop or are destroyed."Resistance is always either partial (as in tomatoes to wilt) or complete (as with flax to wilt). Since there are so many agencies which cause disease in plants, it is evident that the ability to resist disease may depend on any one of many characters or may involve every function of the plant. As the ability to resist is a sign of physiological individuality of the plant, resistance may be inherited. This is strongly shown in the resistance of certain natural species.

Freeman says it is important not to confuse the terms disease escaping, disease-enduring, disease-resisting, and immune varieties. (13) The essential character of true resistance (Ward, Salmon, Orton) lies in a protoplasmic activity and is independant of inoculation accidents.

"A variety may escape a disease thru certain peculiarities of physiologic host activities(as apparent temporary resistance of tomatoes to baeterial wilt) of meteorological conditions, or of certain morphological host characters."

Disease enduring and disease resisting are different tho no sharp line of demarkation can be drawn between the two. Immune varieties possess perfect resistance" (13).

Babcock and C lausen (1) say that"the diversity between varieties in respect to disease resistance is sometimes due to morphological or anatomical peculiarities which prevent invasion of parasites. For example, pubescence or waxy excretions on the surface of plant tissue sometimes prevents plant disease. The number of stomata or the arrangement of cells beneath them may condition fungus infection. A difference of two days in time required for germination may be the deciding factor in smut infection. Certain varieties of potatoes are able to form a corky layer in about six hours after being cut while others require three or four days. Bacteria require 12-24 hours in which to commence putrefaction thru enzymatic action."

"The theory which seems most probable as the cause of resistance in plants is that resistance is due to the absence of response to a specific stimulus (Ex. grape phylloxera) (1)".

The nature of disease resistance has been divided by Orton (22b) into 4 classes; 1- a specific reaction on the part of the host cell against a true parasite,2--structural differences which occur in troubles due to wound parasites,3--Disease endurance, and 4--Disease avoidance as extra early cowpeas which escape wilt and root-knot by maturing before the troubles occur.

"The way true resistance in a plant is developed is by means of a very gradual building up of partial immunity to every fungus which is sufficiently aggressive to be one of the limiting factors in the development of the host"(22b).

Tisdale (35A) has shown that in the case of Fusarium conglutinans (cabbage yellows) and F.lini (flax wilt), the fungus in each case gains entrance thru the root hairs by means of penetration hyphae. F. lini may also penetrate the young flax

plant at any point thru the seed, leaves,stems or roots. F. lycopersici has not been found directly in the root hairs but has been proven by Byrd (4) to enter the young roots of the tomato. So far as is known this is the only place in the tomato where infection can take place. Attempts to inoculate thru the stem have been unsuccessful.

"The exact method of penetration thru cell walls is not known but Wards explanation (Annals of Bot.vol.16) is that the fungus protoplasm overcomes the resistance of the cells of the host by means of enzymes or toxins. Under these conditions the cell wall may be dissolved, or the cell protoplasm killed,or perhaps both occur simultaneously. It is possible the F.lycopersici gains entrance to its host in this manner".

"Gilman (Wis.Sta.)(36A) believes that the yellowing of cabbage is due to the slow drain made by F.conglutinans on the water supply combined with the high temperature which causes an increas ed growth of the fungus and which increases the transpiration of the plant. This seems reasonable as far as it goes but it does not seem sufficient for a complete explanation. If it were a case of the water supply being cut off by clogging of the vessels, we should not expect so much of the one sided wilting which is so common with flax (and as noted above also occurs with tomatoes). In flax the leaves on one side of the stem may become yellow while those on the other side remain perfectly normal. If this wilting were due to the mere cutting off of the water at some point, it is reasonable to expect that when a normal plant is cut half way thru it would turn yellow and wilt on one side. Flax plants were cut in this way(Wisc) but none of them showed any yellowing or wilting from the wound. It is certain that by the

time the foliage of the plants begins to wilt, the root system has been invaded rather severly by the fungus and the root hairs largely destroyed."

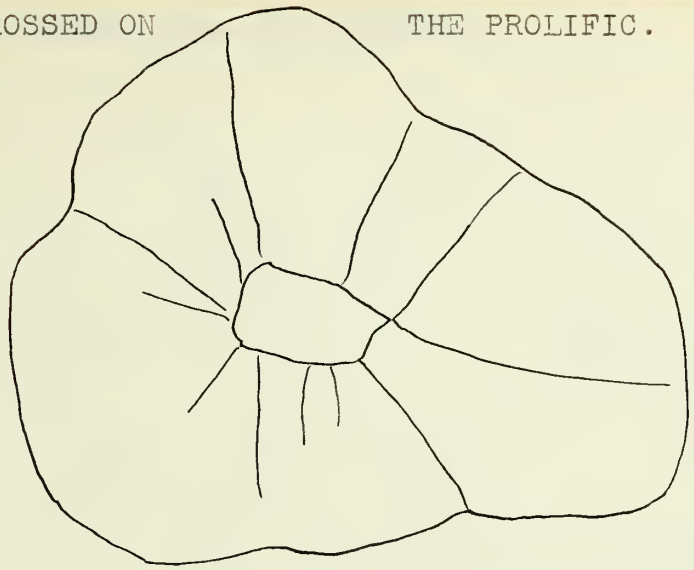
"Experiments with Fusarium oxysporum (41) have confirmed the view that the wilting of potato plants when attacked by this fungus is not due to a mechanical plugging of the vascular tubes but is due to certain products of the fungus acting on the host tissue. The exact nature and chemical composition of the substance or substances responsible for the wilting are being investigated."

If the ideas advanced by Gilman and Young are true, the direct cause of wilt in the tomato cannot entirely be traced to a mechanical stoppage of the water tubes. Pritchard of the U.S.D.A. (26) believes that the clogging up of the vascular system is only part of the explanation of the wilting which occurs in tomatoes.

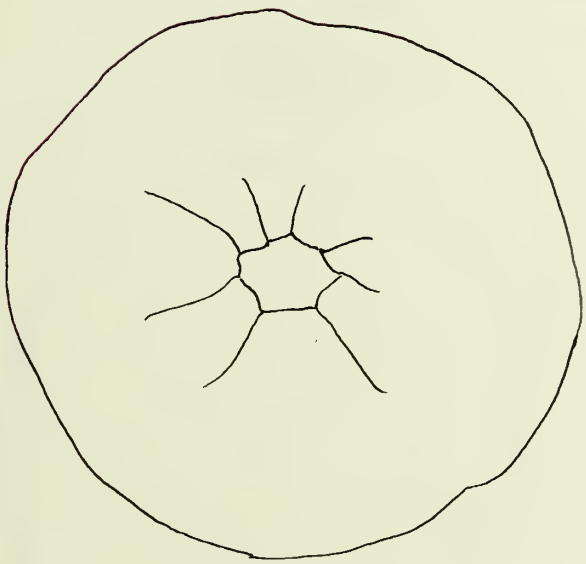
Tisdale (36A) concludes" that the resistance of flax to F.lini is largely of a chemical nature,and the degree of resistance depends to a considerable extent on the particular strain and the environmental conditions associated with it." The exact nature of the resistance of tomatoes to F.lycopersici is a problem which remains for the investigators to work out in the future.

VI EXPERIMENTAL

Methods and Materials--On Sept. 23 1920, seed of the tomato varieties P.R.443 (nos.16,17,18),Norton (nos.10,11,12) Suttons Best of All (4,5,6) Marvel (nos.7,8,9), No.324 (nos.13,14,15), Diener (nos.19,20,21),Prolific (nos.1,2,3),Imperial (nos.22,23,24) and New Century (nos.25,26,27) was sown in flats. The object in view was to raise plants of each variety for use in breeding early, resistant tomatoes. Seed of all varieties germinated well and on Nov.12 three plants of each variety were set in the benches.



Prolific (Plant 3)



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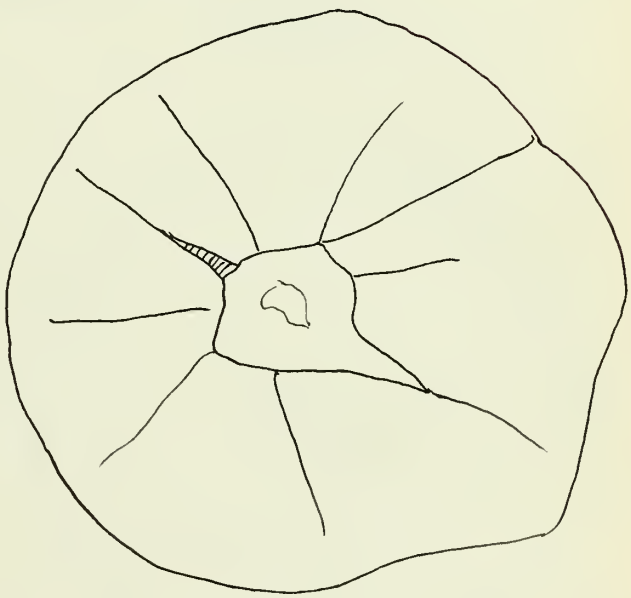

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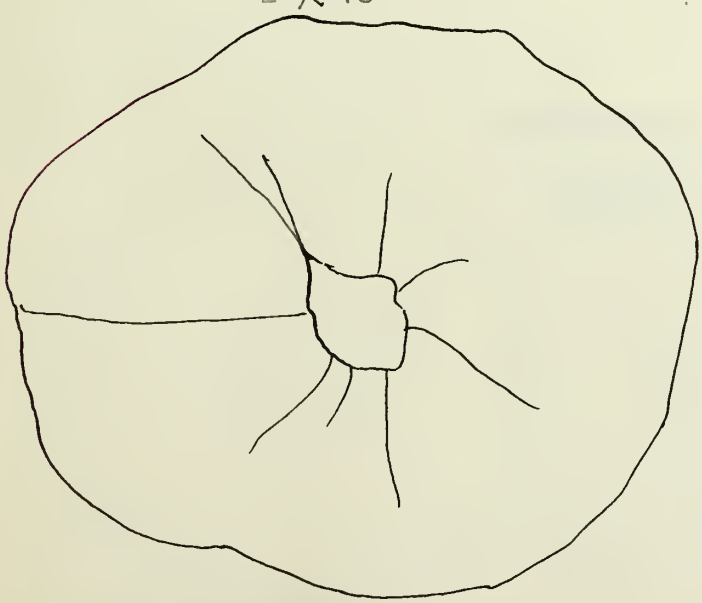

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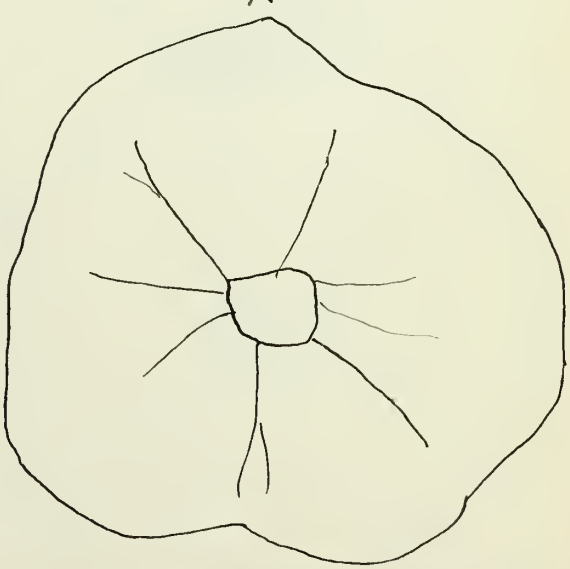

2 X Best of All.

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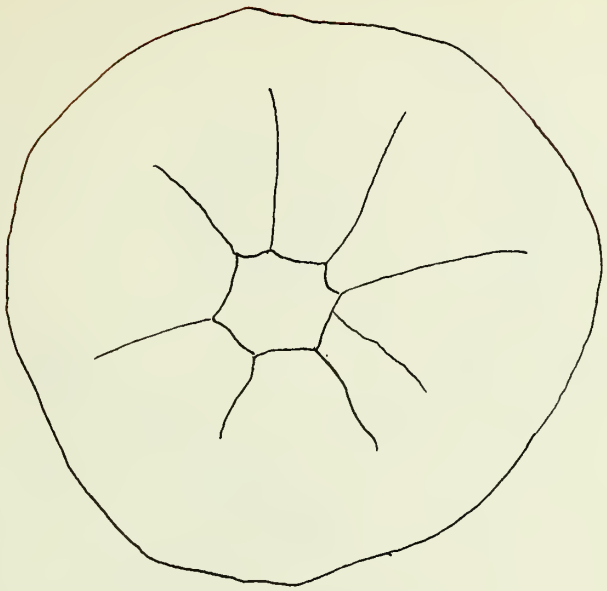
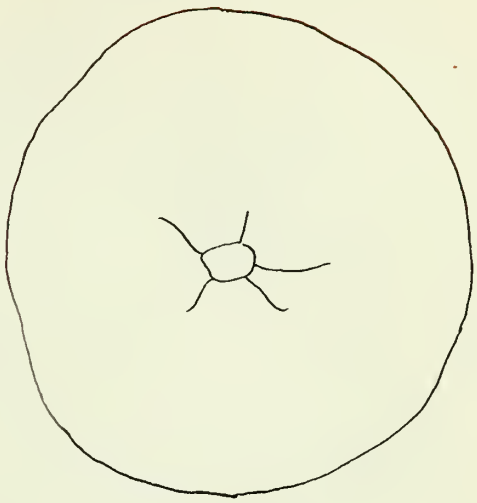
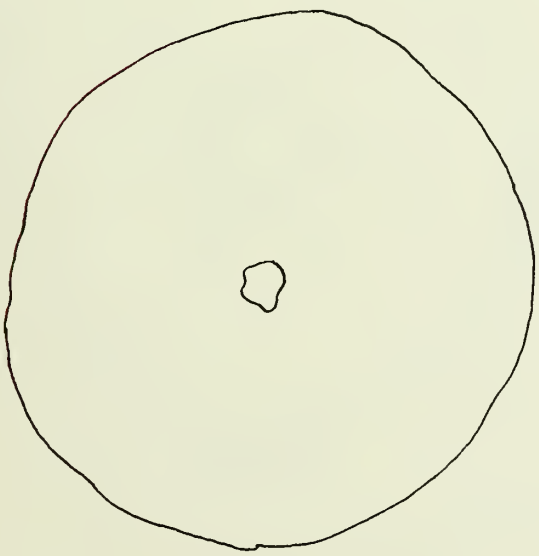


Imperial



22 X 25



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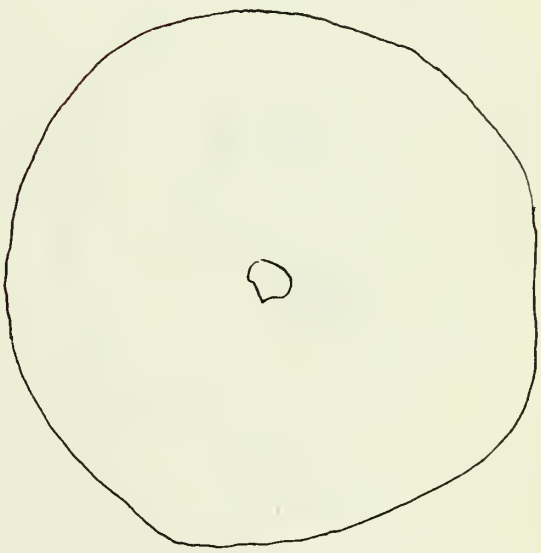

22 X 25

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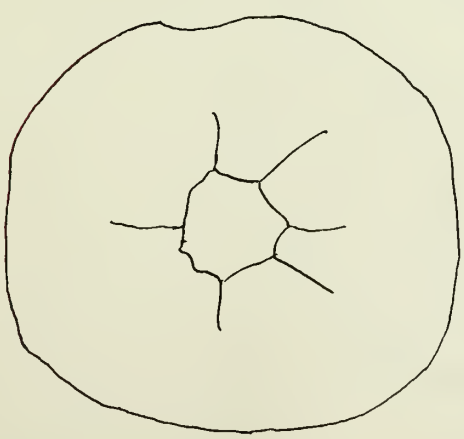

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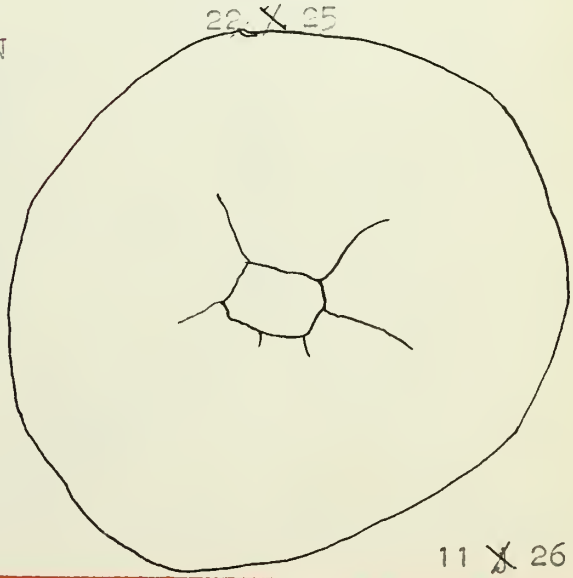

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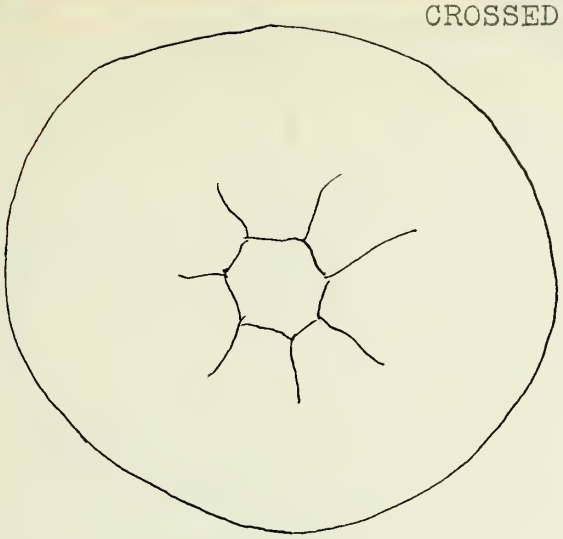

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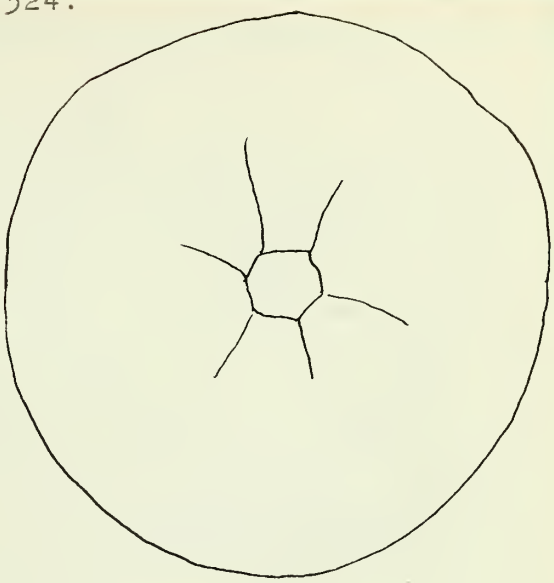

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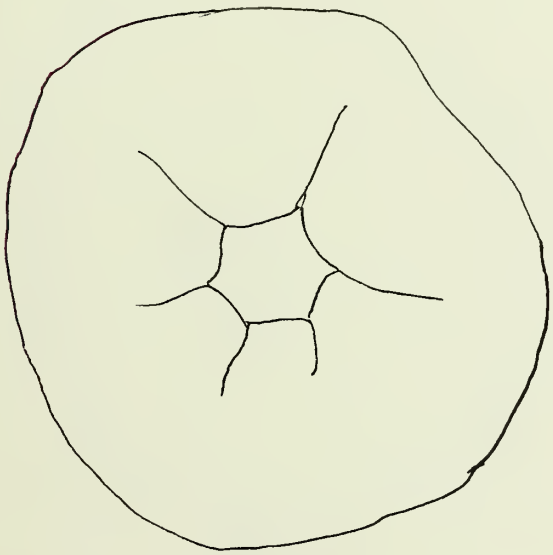

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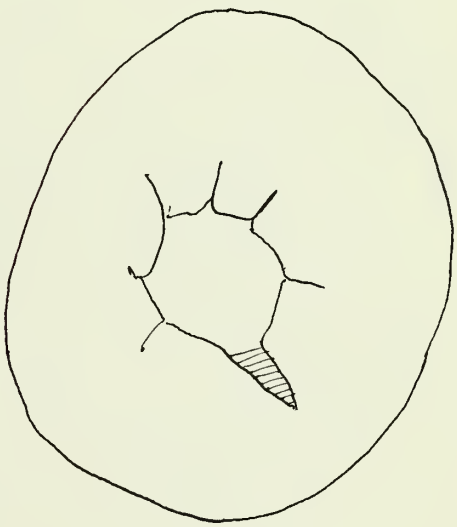
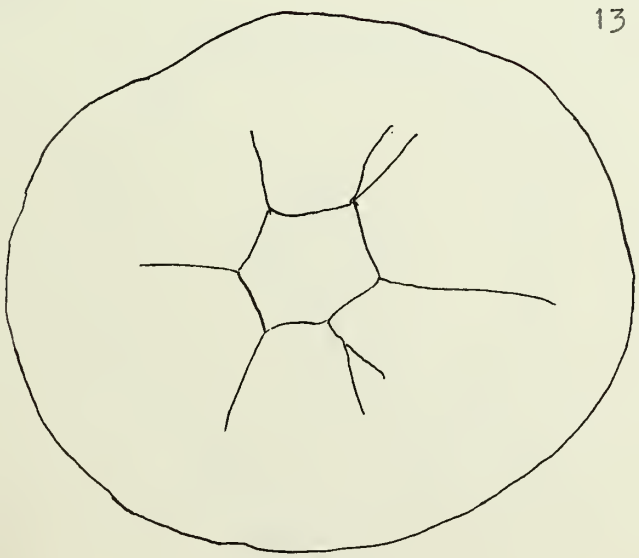


13 X B.B.



15 X 3.

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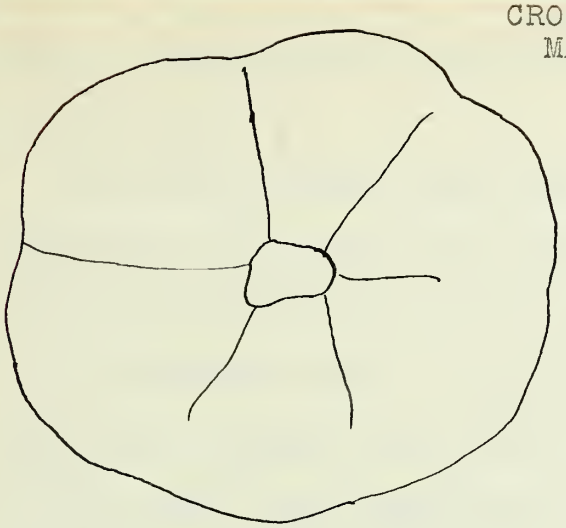
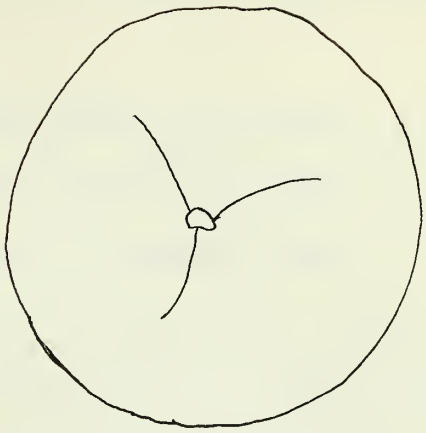
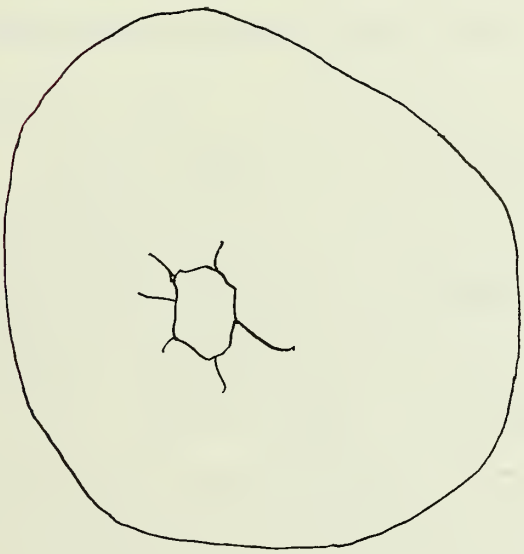
MARVEL.



Marvel.



Best of All.



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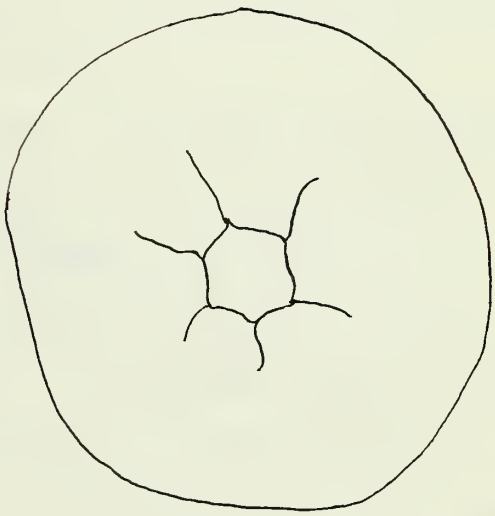

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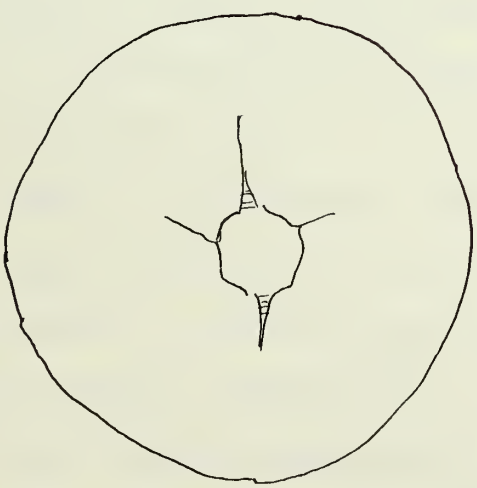


28 X 30

Plants were spaced 2 feet by 16 inches and all the plants trained to one stem.

The first crosses were made on Dec.16 and the method of procedure was as follows; the tomato flower was emasculated before it burst.However, the flower was very near the opening stage. Altho it is considered best to remove all other flowers in a cluster after the desirable one has been emasculated,in our fall crop one or two extra, very immature blooms were left on because of chance for failure in setting fruit. Some of the varieties had large compound clusters which could be bagged in part without disturbing the rest of the cluster. (Ex.Prolific).

After bagging the emasculated bloom, the flower was allowed to stand for two or three days depending some on the maturity of the flower and the brightness of the weather. At the time of bagging, small tags were used to designate the names or numbers of the two parents and in each case that of the female was expressed first. The next procedure was to secure pollen from the most desirable plant representing the male parent.The pollen was shaken from the flower on to a glass slide, then carried to the female parent where the stigmatic surface of the emasculated bloom was covered with pollen. It was essential to apply the pollen over the entire surface else irregular,rough or lop-sided fruit resulted, as shown in two or three of the crosses. When the flower was pollenated, it was bagged up again to avoid any possibility of entrance of foreign pollen. As soon as the fruit had set the bags were removed. It was observed that varieties with large blooms required a longer period between emasculation and pollenation than other types. The writer believes that 4or 5 days are not too long a period for tomatoes of this kind. (See 3,12,25,38,39)

THE FRUIT RESULTANT FROM THREE OF THE BEST CROSSES. (Photo Feb. 1921)

Out of 28 attempts at crossing 20 fruits were produced. The accompanying diagrams give an idea of the size and shape of several of the most promising crosses. Except in the case of the Porto Rican tomato(discussed later under xenia) it may be said that the hybrid fruit in practically every case resembled the female parent characters, in the matters of size,shape, and color in the fruit.It is not until the first and subsequent generations that the various factors in both the fruit and vegetative parts of the tomato split up and follow more or less in accordance with the Mendelian principle.

Comparison of the F_1 generation with Parents--As has been shown, our primary object in the work of this thesis was to produce hybridized strains of tomatoes showing a marked resistance to wilt. In order to produce strongly disease resistant plants of any sort, the latter must be grown under conditions where the disease is particularly virulent. In this instance, badly diseased soil is quite essential for producing resistant strains. The parent and hybrid plants which we desired to test were grown constantly on soil which was obtained from the cylindrical crocks mentioned in Chap III. The soil in 7 of these had produced badly diseased plants and was mixed with the soil from two other crocks which had been treated similarly but where the plants did not show the disease. The following parent and hybrid plants were tested, Marvel, Marvel-443,No.443, 443-Diener, Marvel-Best of All, Best of All, Prolific,Prolific-Imperial. The seed was sown Feb 26 and on Apr.2, 15 plants of each variety(except Prolific-Imperial) were set in 4-inch pots using the same diseased soil as was used for thegrowing of seedlings.5 plants of each variety were also set in 4-inch pots containing a soil which was a yellow clay,

presumably diseased, from Anna, Union county, Illinois, where fusarium wilt has been bad in recent years. Late in April it soon became apparent that the 4-inch pots were inadequate for the rapidly growing tomatoes. Consequently 5 plants of each variety (8 of Prolific) were transplanted to 6-inch pots, two plants on Anna soil and three on local.

Observations were made on the crosses and their parents at various times up to May13. The first date at which wilt appeared was April 1 or 33 days from the time the seed was sown in diseased soil. It was the Prolific variety, again proven very susceptible. On Apr.16 the plant was entirely dead. By Apr.19 four plants had taken the disease and another succombed to the wilt at about that time.

The next in order of susceptibility was the cross, Marvel--443. Apparently here the Porto Rican tomato weakened the strain as 5 out of 11 plants sectioned May7 had taken the disease. At least 2 of the plants in 6-inch pots were diseased May 13.

Best of All had 4 out of 10 (and one incipient) when examined for wilt May 4. The plants in 6-inch pots did not show blackened bundles when removed May 13.

Marvel-Best of All is a very promising cross. Only 3 out of 12 plants showed the disease, internally, May 7. The Marvel parent was the most resistant, showing only one slightly diseased plant out of 9 on May 7. Those in 6-inch pots by May 13 had no external symptoms but had black bundles inside.

The crosses which offer an opportunity for improvement are Marvel-Best of All, 443-Diener, and possibly Marvel-443. Three plants of each of these which proved most resistant are being saved for seed.

In general, the tests on resistance of these tomatoes have not been as satisfactory as could be desired because we have been cramped for room. Greenhouse conditions are not as desirable for tests of this nature as are field facilities. The use of 4-6 inch pots checked the plants so that they were checked and therefor not growing under natural conditions. The small number of plants under test was another drawback for efficient resistance data.

In these tests the Porto Rican variety was a disappointment. Because of its extreme vigor of growth, earliness and relative freedom from disease in Porto Rico, the writer felt he had secured a wilt-resistant type. In the matters of vigor and earliness 443 variety has surpassed the others under test at Illinois. During the early part of the resistance trials and even at later dates, external symptoms of wilt were not nearly as serious as on some of the other varieties. But when the plants were examined internally 6put of 11 in 4-inch pots and 3 out of 5 in 6-inch pots were diseased. The value of the P.R.443 tomato will perhaps lie in its extreme earliness and vigorous growth.

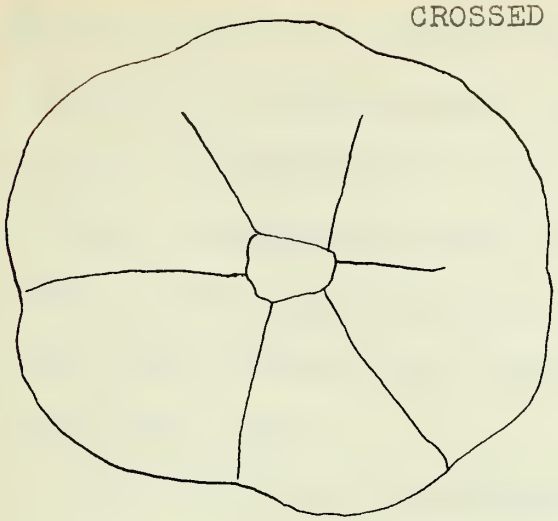
Discussion of Results--Xenia : As the results have been very ~~very~~ largely discussed in the foregoing pages, attention will be directed, breifly, to the matter of xenia. Coulter (Plant Breeding), says tha"when a yelow or white corn is crossed with pollen from a race of red corn, many of the resulting grains are red or mottled. This fact was noted as far back as 1881. The name"xenia" was given by Focke to indicate the direct effect of foreign pollen." This direct effect gives an explanation for the xenia which has occurred in our tests with tomatoes."Sine 1898 the phenomenon has been explained by the discovery of double fertilization in all flowering plants. Statements in the Experiment Station Records

call attention to the occurrance of xenia in corn,rice,beans, walnuts,mustard, pears,and tomatoes. In the case of corn, xenia is not explained on the basis of the"direct effect of foreign pollen" because the pollen in maize is indirect in its action. The tomato seed does not have an endosperm corresponding to that which is present in the case of corn. (C.W.Woodworth U. of Ill.) "Not only is the embryo a product of a fusion with a male cell (corn) but the endosperm is also a product of a fusion with a male cell and these immediate influences of the pollen parent are shown by the endosperm in the way it has become possible in several cases to get the characters of the pollen parent in the fruit of the pistillate parent." (Coulter).

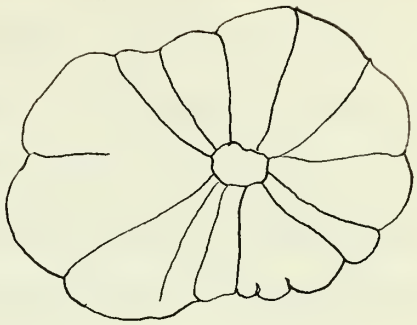
Waller (37A) decsribes xenia in the words of" hybridization exposed". It is pointed out that the xeniophyte like the sporophyte is a fusion product, the egg nucleous of the latter fusing with one male nucleus, while in the former the second male nucleus and the defenite nucleus fuse. The defenite nucleus forms upon the fusion of two nuclei from opposite poles of the female gametophyte, the fusion nuclei appearing after 3 successive divisions of the megospore nucleusduring which the egg is differentiated. In xenia, variation is said to appear as a direct result of the of the introduction of hereditary factors.

Groth (15) in his work with tomatoes states"that "peach" flowers fertilized with pollen from other types generally develop into fruits differing in no way in appearance from normal peach fruits. Sometimes, however,they develop into apparently shiny fruits. These shiny fruits have evidently less hairs than normal "peach"fruits. When placed side by side with fruits of other types they do appear somewhat duller, but when compared with typical

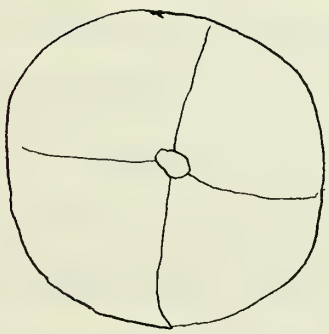
CROSSED ON PORTO RICAN
443



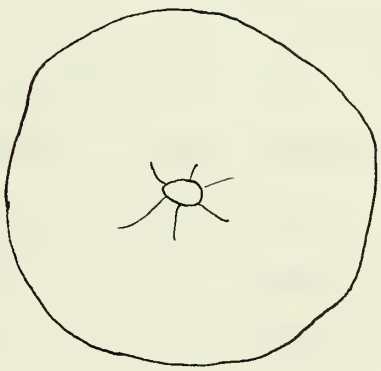
Marvel.



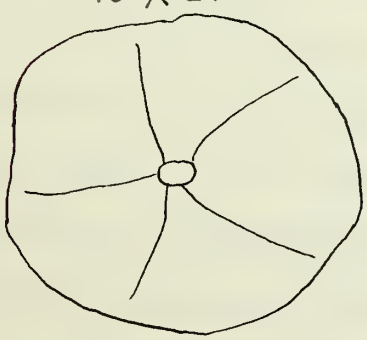
P.R. No. 443.



16 X 24



17 X 7



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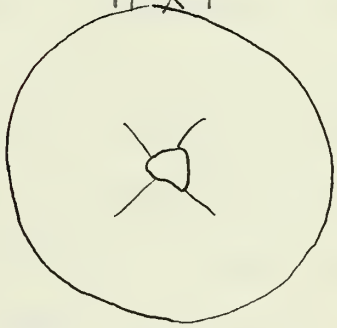
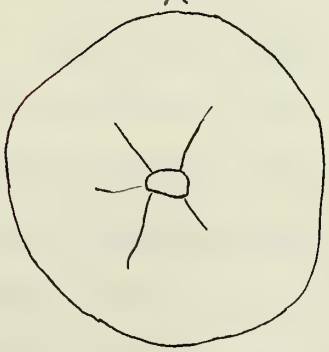
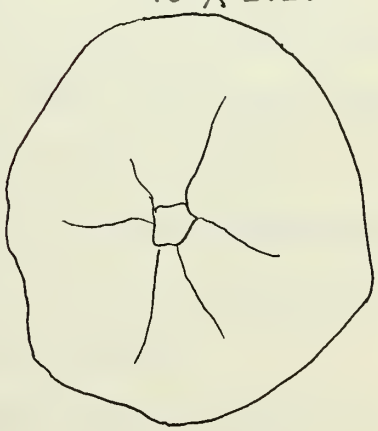


16 X B.B.



29 X B.B.



29 X Diener.

"peach" fruits they appear decidedly shiny. Such fruits may be borne in the same cluster with dull fruits, altho all the fruits in the cluster may have been fertilized by pollen from the same flower. Sometimes the fruit may appear shiny on one side or on the stem end only". Because of this behavior, Groth concludes, "that when crossing the rough "peaches" with smooth types partial xenia may occur."

The drawings on accompanying page show strongly the effect of xenia produced by foreign pollen on the shape of certain tomato fruits. The writer is unaware of any record of xenia occurring in the fruits of the tomato such as is represented here. Two parents, the Marvel and 443 are illustrated as also a resultant cross is shown as 17/7. The Marvel is ordinarily a smooth tomato while the Porto Rican is invariably much ridged and many celled as the figure indicates. The outline of the cross (natural size) shows that in the matter of shape the fruit is symmetrical and 6-celled as is the pollen parent and not rough and many celled as is the female parent. Five other examples of xenia are shown on the same page. In two cases the fruit is 4-celled and in two others 5-celled. Illustrations (16/24) are given in which the pistillate and staminate parents were the same in each case. It will be noted that in one cross, a 4-celled fruit was produced and in the other the result was 5-celled. This shows that the cell number in xenia is not correlated with parent types.

From the standpoint of shape, not from color, size, pubescence, or broken center (as #443), xenia may be said to occur in tomatoes of certain types which have been crossed as the above.

The summary which follows calls attention briefly to some of the more important points brought out in this thesis.

VII SUMMARY

Fusarium wilt is a very destructive disease of tomatoes especially in the Southern States, in the Ohio Valley and south of the Missouri River.

The disease may attack plants at any stage of growth. If tomatoes are affected while young, they may be killed before setting fruit. In the field or greenhouse, the usual stage at which the wilt appears is when the vines have set fruit. Under these conditions a few early fruits may be ripened before the plant dies.

Fusarium wilt differs from Bacterial Wilt in that the former brings about a more gradual death of the plant. Fusarium wilt is carried usually thru the soil while bacterial wilt is frequently spread by insects. The Blights of the Pacific Northwest are caused by fusaria which attack only the roots of the tomato. F.lycopersici attacks the vascular system of the stem as well as the root.

The causal organism,F.lycopersici,is subterranean in its action. 28 degrees C is its optimum temperature for growth. The organism can live in the soil on tomato refuse or exist as chlamydospores for a period of 3 or 4 years.

Resistance trials on a number of varieties showed that "Prolific"is the most susceptible and that"Marvel"and "Diener" are the most resistant.

Root pruning tests showed that tomatoes with injured roots contracted the disease several days earlier and succombed to wilt more readily than those with roots unpruned.

Rotation and the use of wilt resistant varieties are the most promising control measures for the disease.

Within certain limits, the breeding work for disease resistance done by other investigators may be applied to this study. Wilt resistance in the tomato is inherited as a recessive factor.

Nine varieties of tomatoes (5 resistant and 4 susceptible) were used for breeding purposes. Out of 28 attempts at crossing 20 hybrid fruits were secured. 4 crosses and 4 parents of the crosses were tested for disease resistance on badly infested soil. The two most resistant crosses proved to be Marvel- Best of All and 443-Diener. The Marvel tested highest in point of resistance.

Xenia in shape occurred on crosses involving the Porto Rican tomato 443 as female parent and the large, smooth-fruited types as male parents. The resultant fruit was smooth and few celled following the staminate parent rather than rough and many celled as is usual with the pistillate parent.

Other crosses, almost without exception, followed the factors for shape size and color which were typical of the female plant on which the fruit was borne.

VII BIBLIOGRAPHY.

(1) Babcock and Clausen---" Genetics in Relation to Agriculture". Chap. 24 on "Disease Resistance".

(2) Bewley, W. F. ------- 1921 English Experiment and Research Station, a letter.

(3) Bouquet,A. B. ------- 1919 Oregon Bul. 158,"Pollenation of tomatoes".

(4) Byrd,P. J. ------- 1921 M. A. from Illinois.

(5) Carpenter,C. W. ----a.1918, Jour. Agr. Res.vol.12 no.9 p 529 "Diseases of Okra and Verticillium Wilt.

--- b.1916, Jour. Agr. Res.vol.5 no.5 p.183 "Fusaria of Potatoes".

(6) Clayton,E. E. ------ 1920,Jan. Phytopathology,vol10 p.63. "Relation of soil temperature to tomato wilt".

(7) Conn. Sta. Rept.----- 1890,p.95 F.lycopersici on tom.fruit.

(8) Cromwell,R. O. ----- 1917,Jour. Agr. Res.vol.8 no11 p 421, "Fusarium of Soybeans".

(9) Durst,C. E. ----- 1918,Phytopath.vol.8 p.8, "Wilt and resistance in Illinois".

(10) Edgerton,C. W. ---a. 1920, La. Bul.174,"Tomato Wilt".

b. 1916 Phytopath.vol.6 p.102,"A new method of testing wilt resistant strains of the tomato".

c. Letters 1920-21.

d. 1914, La. Bul.142 "Tomato diseases".

(11) Essary,S. H. ---- 1912,Tenn.BUL 95 "Wilt Resistance studies". (tomato).

(12) Fletcher,S. W. -- 1907 Mich. Spec. Bul 39 "Pollenating Tomatoes".

(13) Freeman,E. ---- 1911 Phytopath. vol.1Ø pp.9,10,115,"The Relation of resiatance to immunity in plant diseases."

(14) Georgia Sta.rept 1917 pp.141-151.

(15) Groth,B. H. A.- 1912 N.J.Bul.242,"F_1 Heredity in size, shape and number in tomato fruits".

(16) Harter,L. L.--- 1920 Phytopath. vol.10,p.306-7,"Sweet potato stem rot and Tomato wilt".

(17) Higgins,B. B.-- 1921 Letters and Chicago address 1920.

(18) Humbert,J. G. --1916 Ohio Bul. 321"Diseases of Tomatoes".

(19) Humphrey,H. B.- 1914 Wash. Bul 115"Studies on the Relation of certain species of Fusaria to the Tomato Blight of the Pacific Northwest".

(20) McClintock,J.A. 1920 Ga. Bul. 138 "Tomato Wilt".

(21) Norton,J. B.--a 1920-21 letters.
b 1917 Trans. Peninsula Hort. Soc. Dover Del. "Canning tomatoes resistant to Fusarium".
c 1917 Dec.15 Market Growers Journal"Wilt and Resiatance Studies".
d 1914 Md. Bul 180"Resistance Tests".

(22) Orton,W. A. - a 1918 Amer. Jour. Botany,"Breeding for Disease Resistance in Plants".
b.1908 U.S.D.A. Yearbook,"The Development of Disease Resistant Plants".

(23) Penn.Sta.Rept. 1915-16 "Notes on some Tomato Diseases".

(24)Pl.Disease Surveys1918-20 U.S.D.A. Supplements 10-12.

(25) Price and Drinkard --- 1908 Va. Bul.177"Cross Breeding Tomatoes".

(26) Pritchard,F. J. 1920-21 Letters from U.S.D.A physiologist.

(27) Rosa Jr. J. T.- 1921, a letter.

(28) Rolfs,P. H. --- 1913 Fla. Bul.117 "Tomato Diseases".

(29) Sanford,E. E.-- 1917 N.C. sta. Rept." Studies on the Resistance of tomatoes to Bacterial wilt."

(30) Selby,A.D. --- 1921 Letter from Ohio Botanist.

(31) Sherbakoff,C. D.1917 Fla. Bul. 139 "Tomato Diseases".
b.1918 Fla. Sta Rept. pp 71R to 74R on "Solanaceous Blight." (bacterial wilt)

(32) Schwarze,C. A. 1917 N. J. Bul. 313" Parasitic Fungi of New Jersey."

(33) Smith,E. H.----- 1921,Letters and pure cultures from California.

(34) Stoddard,E. F.-- 1918,Mk. Growers Journal,"Tomato Wilt".

(35) Stuckey,H. P.--- 1916,Ga.Bul.121 "Transmission of Resistance and Susceptibility to Blossom-End-Rot in Tomatoes".

(36) Temple,C. E.--- 1919,Trans.Pen.Hort.Soc."Progress in the Control of Wilt and Blight of Tomatoes".

(36A) Tisdale,W. H.-- Jour. Agr. Res.vol.11 p.573-606 "Flaxwilt".

(37) Va. Sta. Rept.-- 1915-16 pp.187-192 (on tomato wilt) .

(37A) Waller,A. E.---- 1917 Ohio Jour. Science 17,no.8 p.273-284 "Xenia and other Influences following Fertilization".

(38) Wellington,R.--a.1920,Trans.Pen.Hort.Soc."The Use of Tomato seed Resistant to Wilt Disease".
b.1912 N.Y.(Geneva) Bul.346 "Influence of Crossing in Increasing the Yield of the Tomato".

(39) White,T. H. --- 1918 Md. Bul.222 pp93-101."The Pollen-of Greenhouse Tomatoes".

(40) Wollenwebber, H.- 1913 Phytopath. vol.3 p.35,"The Wilt Disease Problem".

(41) Young and Bennett C. W. --- 1921 Jan. Phytopathology.

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Signed A. L. Griffith.

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